

Board of Pharmacy

Initial Statement of Reasons

Subject Matter of Proposed Regulation: Pharmacy Technicians Checking Pharmacy Technicians in Acute Care Hospitals

Sections Affected: Amend 1793.7 and Add 1793.8

Specific Purpose of the Proposed Changes:

Section 1793.7(b) (Amended)

This section requires that any function performed by a pharmacy technician in connection with the dispensing of a prescription, including repackaging from bulk and storage of pharmaceuticals, must be verified and documented in writing by a pharmacist. The amendment would allow general acute care hospitals licensed under Health and Safety Code Section 1250(a) to establish programs to use pharmacy technicians in hospital inpatient pharmacies to check other pharmacy technicians for filling floor stock, ward stock and unit dose cassettes; this program is commonly known as tech-check-tech, or TCT.

Section 1793.8 (Add)

This section establishes requirements for general acute care hospitals to employ specially trained pharmacy technicians to check the work of other pharmacy technicians filling floor stock, ward stock, and unit dose cassettes.

Factual Basis

This proposed regulation will permit general acute care hospitals to employ specially trained pharmacy technicians in place of pharmacists to check the work of other pharmacy technicians filling floor stock, ward stock, and unit dose cassettes. Hospitals with a TCT program will be required to re-deploy pharmacists to the inpatient care setting to provide clinical services. Prior to initiating a TCT program, a general acute care hospital pharmacy will be required to have on file a description of the clinical pharmacy program.

To ensure quality patient care and reduce medication errors, the regulation will also require that a TCT program have the following components:

- The overall operation of the program shall be the responsibility of the pharmacist-in-charge.
- The program will be under the direct supervision of a pharmacist and the parameters for the direct supervision shall be specified in the facility's policies and procedures.
- The pharmacy technician who performs the checking function must have received specialized and advanced training as prescribed in the policies and procedures of the facility.

- There must be ongoing evaluation of each program that uses pharmacy technicians to check the work of other pharmacy technicians to ensure the quality of patient care and reduce errors.

Pharmacy technicians have been used in the hospital setting in California for decades. In 1991, California enacted statutory provisions allowing the use of Board of Pharmacy-registered pharmacy technicians in community pharmacy setting for the first time (AB 1244, Chapter 841, Statutes of 1991). This same legislation exempted technicians working in hospital settings from the registration requirements. Regulations were developed over the next year to implement this legislation – the statutory and regulations changes prohibited the longstanding practice in hospital settings of technicians checking technicians. Instead, a pharmacist was required to check the work performed by all pharmacy technicians whether in the inpatient or community pharmacy setting. Later, legislation was enacted that required pharmacy technicians in the hospital setting to become registered with the board as well (SB 1553, Chapter 798, Statutes of 1996).

In May 1998, the Long Beach Memorial Medical Center, Cedars-Sinai Medical Center, and the UCSF School of Pharmacy requested a waiver from the board from CCR 1731 to conduct a two-year study to evaluate the effectiveness of TCT programs. The results of this study were published in the June 15, 2002 issue of the American Journal of Health-System Pharmacists, and found that certified pharmacy technicians checking unit-dose cassettes were slightly more accurate than pharmacists performing the same task. (The board approved two extensions of the initial waiver and the TCT program ended in December 2003.)

In April 2004, Cedars-Sinai Medical Center and the UCSF School of Pharmacy requested a waiver from the Board of Pharmacy to conduct a two-year study to evaluate the impact of pharmacists preventing medication errors associated with prescribing and administering medications as a result of pharmacists being re-deployed from unit-dose medication cassette checking to clinical and professional functions. Preliminary results after one year of the study show that re-deploying pharmacists to clinical services has resulted in pharmacists intercepting 1,300 potential prescribing errors; 400 of which had the potential to cause harm to patients. This TCT study is scheduled to end at the end of April 2006. These findings are consistent with other studies that have found that having pharmacists perform clinical services improves patient care and reduces medication errors.

Underlying Data

1. Ambrose P.J., Saya, F.G., Lovett L.T., Tan S., Adams D. W., Shane R.. “Evaluating the Accuracy of Technicians and Pharmacists in Checking Unit Dose Medication Cassettes.” American Journal of Health-System Pharmacists. Vol. 59 June 15, 2002. This study found that pharmacists checking unit-dose cassettes had an accuracy rate of 99.52% compared with 99.88% for certified technicians performing the same task.

2. Bond C.A., Raehl C.L., Franke T.. “Interrelationships Among Mortality Rates, Drug Costs, Total Costs of Care, and Length of Stay in United States Hospitals: Summary of Recommendations for Clinical Pharmacy Services and Staffing.” Pharmacotherapy 2001; 21(2): 129-141. This study found, among other things, that increased clinical pharmacy

staffing in hospitals has a direct relationship with significantly decreasing patient deaths in hospitals.

3. Leape L.L., Cullen D. J., Clapp M. D., Burdick E., Demonaco H. J., Erickson J. I., Bates D. W.. "Pharmacist Participation on Physician Rounds and Averse Drug Events in the Intensive Care Unit." Journal of the American Medical Association. Vol. 282(3), July 21, 1999, pp. 267-270. This study found that having a pharmacist participate in morning medical rounds with physicians, nurses, and attending staff led to pharmacists interventions that corrected incomplete prescriptions, wrong dose, wrong frequency, inappropriate choice of medication, and duplicate drug therapy.

Business Impact

This regulation will not have a significant adverse economic impact on businesses. The proposed regulation does not require that hospitals have a TCT program. Hospitals that choose to implement a TCT program are required to redirect pharmacists who formerly checked unit dose cassettes to perform clinical services in the hospital. Hospitals and health care payers may see costs saving from implementing a TCT program as redeployed pharmacists perform clinical services which will result in fewer medication errors, better patient care, and reduced patient stays in hospitals.

Specific Technologies or Equipment

This regulation does not mandate the use of specific technologies or equipment.

Consideration of Alternatives

No reasonable alternative to the regulation would be either more effective in carrying out the purpose for which the action is proposed or would be as effective and less burdensome to affected private persons than the proposed regulation.

Evaluating the accuracy of technicians and pharmacists in checking unit dose medication cassettes

PETER J. AMBROSE, FRANK G. SAYA, LARRY T. LOVETT, SANDY TAN, DALE W. ADAMS, AND RITA SHANE

The rapidly changing health care environment necessitates that health care organizations optimize limited resources while improving the quality of care provided. Medication-related complications cost the American health care system as much as \$177 billion annually.¹ Pharmacist expertise in drug therapy has repeatedly demonstrated improved patient outcomes, fewer complications, and better control of the cost of medication use.²⁻⁴ However, there currently is a critical shortage of pharmacists, as documented in the Department of Health and Human Services report to Congress on the pharmacist workforce.⁵ This shortage is especially acute in California, where the ratio of 58 pharmacists to 100,000 people in the population is well below the national average of 71 pharmacists to 100,000 people in the population. In this same report, the Pharmacy Manpower Project Aggregate Demand Index for California indicated a high

Abstract: The accuracy rates of board-registered pharmacy technicians and pharmacists in checking unit dose medication cassettes in the inpatient setting at two separate institutions were examined.

Cedars-Sinai Medical Center and Long Beach Memorial Medical Center, both in Los Angeles county, petitioned the California State Board of Pharmacy to approve a waiver of the California Code of Regulations to conduct an experimental program to compare the accuracy of unit dose medication cassettes checked by pharmacists with that of cassettes checked by trained, certified pharmacy technicians. The study consisted of three parts: assessing pharmacist baseline checking accuracy (Phase I), developing a technician-training program and certifying technicians who completed the didactic and practical training (Phase II), and evaluating the accuracy of certified technicians checking unit dose medication cassettes as a daily function (Phase III).

Twenty-nine pharmacists and 41 technicians (3 of whom were pharmacy interns) participated in the study. Of the technicians, all 41 successfully completed the didactic and practical training, 39 successfully

completed the audits and became certified checkers, and 2 (including 1 of the interns) did not complete the certification audits because they were reassigned to another work area or had resigned. In Phase II, the observed accuracy rate and its lower confidence limit exceeded the predetermined minimum requirement of 99.8% for a certified checker. The mean accuracy rates for technicians were identical at the two institutions ($p = 1.0$). The difference in mean accuracy rates between pharmacists (99.52%; 95% confidence interval [CI] 99.44–99.58%) and technicians (99.89%; 95% CI 99.87–99.90%) was significant ($p < 0.0001$).

Inpatient technicians who had been trained and certified in a closely supervised program that incorporated quality assurance mechanisms could safely and accurately check unit dose medication cassettes filled by other technicians.

Index terms: Administration; Dispensing; Drug distribution systems; Personnel, pharmacy; Pharmacists, hospital; Pharmacy, institutional, hospital; Professional competence
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level of demand for pharmacists. The current shortage of pharmacists poses a significant challenge to providing and maintaining the desired level of pharmaceutical care.⁶

The importance of pharmacy technicians in ensuring the efficient operation of hospital pharmacies is widely recognized. By reassigning nondiscretionary drug distribution tasks to pharmacy technicians, pharmacists can be redeployed to prevent adverse drug events and ensure optimal medication use. In California, unit dose medication cassettes that are filled by pharmacy technicians must be checked by a pharmacist. Pharmacists spend one hour per day checking technician-filled medication cassettes, which competes with the increasing demands on pharmacists to provide clinical services and become more involved in medication safety initiatives, in addition to dealing with the increased complexity of hospitalized patients and the pharmacist shortage. Expanding the role of technicians by implementing a structured training program with ongoing quality assurance measures may ease the impact of the pharmacist shortage through the judicious and appropriate use of skilled support personnel and increase the time available to pharmacists to perform clinical functions.

Background

In 1997, the California State Board of Pharmacy was petitioned to authorize board-registered pharmacy technicians to check unit dose cassettes filled by other pharmacy technicians in the inpatient environment. In response to strong opposition from some professional organizations and community pharmacists, who were concerned that the exemption could be expanded outside of the inpatient pharmacy environment and jeopardize pharmacist jobs, the board voted not to grant this petition. However, the board did express a desire to receive additional evi-

dence to further evaluate allowing pharmacy technicians to perform this function. Thus, Cedars-Sinai Medical Center (CSMC) and Long Beach Memorial Medical Center (LBMMC) petitioned the board to grant a waiver of the California Code of Regulations to conduct an "experimental program" under the direction of the University of California, San Francisco, School of Pharmacy. The purpose of the program was to compare the accuracy of unit dose medication cassettes checked by pharmacists with those checked by trained, registered pharmacy technicians in the inpatient setting. In May 1998, the waiver was granted for the experimental program known as "Evaluating the Use of Board Registered Pharmacy Technicians in a Unit-Dose Drug Distribution System." The waiver was initially granted through November 1, 2000, and was extended to December 2002 on the basis of data generated from this study, which was presented to the board in January 2001.

CSMC is a 900-bed, acute tertiary care hospital in Los Angeles, California, and LBMMC is a 540-bed, acute tertiary care hospital in Long Beach, California. The unit dose drug distribution system used by CSMC and LBMMC is diagrammed in Figure 1. It should be emphasized that the process of filling and checking unit dose medication cassettes is preceded by the review and verification of all medication orders by a pharmacist. The pharmacist evaluates the appropriateness of the medication, dose, dosage form, route of administration, and frequency in the order and screens for drug allergies, drug-drug interactions, and contraindications. A pharmacist is also responsible for dispensing any initial medication doses needed before the regularly scheduled unit dose cart distribution.

Pharmacy technicians do not evaluate the accuracy and appropriateness of medication orders. Pharmacy technicians perform manipula-

tive and nondiscretionary functions only under the supervision of pharmacists. When filling a medication cassette with unit dose medications, a technician reads a list of medications (a "fill list") previously verified by a pharmacist, removes the unit dose medication from stock, and places it in a patient's cassette or medication drawer. Next, a "checker" verifies the filled cassette against the fill list to minimize the possibility of errors before the medications are sent to the nursing areas. In California, only a pharmacist can check these unit dose cassettes, which necessitated the waiver from the board of pharmacy to allow technicians to perform this function in this program. It should be noted that nurses also check the medication when removing it from a patient's cassette and confirm it with the medication administration record (also reviewed and approved by a pharmacist) before administering the medication to the patient, in accordance with Joint Commission on Accreditation of Healthcare Organizations and California Department of Health Services requirements. Thus, a medication is triple-checked before it is administered to a patient.

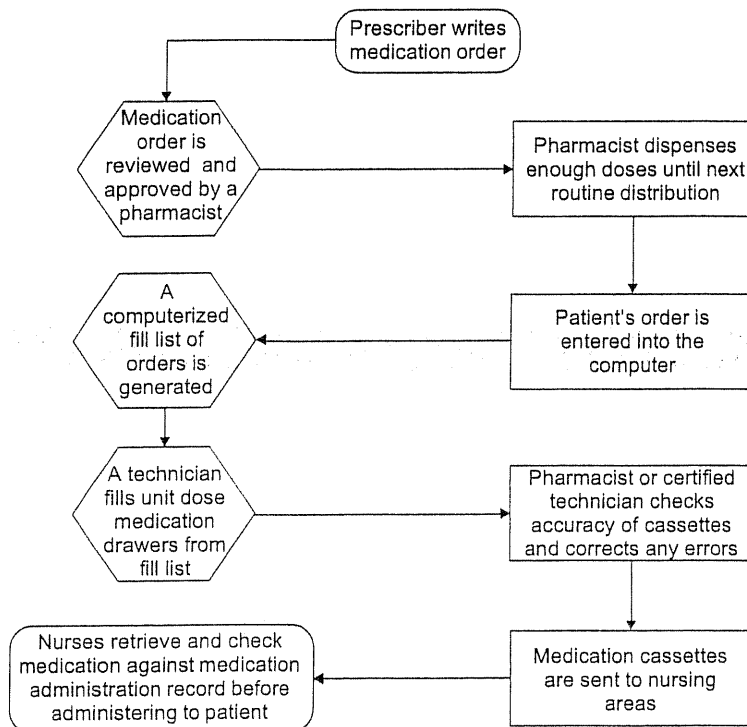
This article describes the experimental program and the accuracy of trained technicians checking unit dose medication cassettes compared with that of pharmacists.

Methods

This study was conducted concurrently at both CSMC and LBMMC and consisted of the following three phases, which were modeled from previous studies⁷⁻¹³:

- Phase I: Assessing the baseline accuracy rate of pharmacists checking unit dose medication cassettes,
- Phase II: Developing a technician training program for checking unit dose cassettes and certifying technicians who successfully completed the training program, and

Figure 1. Diagram of the inpatient unit dose drug distribution system used at both Cedars-Sinai Medical Center and Long Beach Memorial Medical Center in normal practice and during the study.



- Phase III: Evaluating the accuracy of certified technicians checking unit dose medication cassettes by conducting quality assurance audits.

Phase I began in June 1998 with the goal of auditing a minimum of 12,500 doses at each institution. Staff pharmacists checked all unit dose cassettes filled by technicians as was the pharmacists' normal routine during the day shift. They were aware that audits were being conducted. Study participants were selected on the basis of their normal work schedules, and no attempt was made to alter assignments. In addition to any spontaneous errors made by technicians filling the cassettes, artificial errors were randomly introduced by pharmacist "auditors" assigned to oversee the study process. Artificial errors were introduced at a rate of at least one error per 500 doses (0.2%) to coincide with a 99.8% minimum accuracy rate.⁷ The pharmacist checkers documented and corrected

any errors they detected. Subsequently, the pharmacist auditor would audit and verify the accuracy of the pharmacist checker in detecting and correcting artificial and spontaneous filling errors for all doses dispensed during the audit period. Spontaneous and artificial errors overlooked by the pharmacist checkers were documented on an audit form and corrected by the pharmacist auditors before the medication cassettes were distributed to the nursing stations. There were a total of three pharmacists at CSMC and five at LBMMC who were responsible for introducing artificial errors and auditing the pharmacists. In all three phases of the study, an error was defined as a wrong drug, dose, quantity, or dosage form; expired medication; inaccurate concentration; wrong patient's medication cassette; or missing drug.

During Phase II of the program, the pharmacy services departments at CSMC and LBMMC collaborated

on a training syllabus, qualifying examination, and data collection forms. Technicians and pharmacy interns (employed and functioning as technicians) were eligible to be included in the study if they were registered with the California State Board of Pharmacy and had at least six months of experience filling unit dose medication cassettes. They were then given didactic and practical training, in accordance with the approach used by the Minnesota Society of Hospital Pharmacists in a pilot project in which technicians were trained to check unit dose cassettes filled by other technicians.⁷ The didactic component consisted of lectures on the unit dose process, proper packaging and repackaging techniques, medication safety, and basic pharmaceutical calculations. The didactic training concluded with an examination. Technicians were required to achieve a minimum passing score of 80% on the examination. The practical training included observing a pharmacist checking unit dose cassettes and actual hands-on experience. After successful completion of the didactic and practical training, the technicians were audited for accuracy in checking unit dose cassettes for at least 3500 consecutive doses. Artificial errors, as described for Phase I of the program, were also introduced in this process. The audits were conducted by the same pharmacist auditors as in Phase I. To become a certified technician checker in this program, an overall accuracy rate of at least 99.8% was required. This phase of the study began in June 1998 and was continued as new technicians were trained and included in the program.

Phase III began in April 1999. In this phase, certified technician checkers were responsible for checking unit dose medication cassettes as a daily activity while under the supervision of a pharmacist. Monthly quality assurance audits of at least 500 doses were conducted for each certified technician checker, using

the same procedure of introducing random artificial errors as previously described. Accuracy was to be maintained at 99.8% or higher. If a certified technician checker failed a monthly audit, the audit was to be repeated within 30 days. If the technician failed the second audit, the technician would be removed from the checking position until he or she was retrained and recertified. If a certified technician checker did not perform this function for more than three months, an audit would be conducted when the technician restarted checking medication cassettes. If a technician had not checked cassettes for more than six months, recertification was required.

In January 2000, the board approved the following requested amendment to the program: "In Phase III of the study, a monthly audit will be conducted for 3 months, and if the accuracy rate meets or exceeds the minimum target of 99.8% for three consecutive audits, future audits will be conducted quarterly thereafter for that technician. Technicians failing a quarterly audit will have to pass three consecutive monthly audits before resuming quarterly audits." The amendment had been requested by CSMC and LBMMC, since no certified technician had failed a monthly audit.

Error rates were calculated as the number of errors discovered by the auditors divided by the total number of unit doses audited. The accuracy rate was defined as one minus the error rate, which was then converted to a percentage. The 95% confidence intervals for these rates and *p* values for comparing the pharmacist and technician checkers were computed using SAS, version 6.12 (SAS Institute, Cary, NC). An additional analysis was conducted to ensure that wide variation in accuracy rates among individual technicians did not exist, since this could result in a favorable mean accuracy rate and mask the performance of one or more techni-

cians who performed below the established goal of 99.8%. Mixed-effects logistic regression models with a random-checker effect were used to confirm the results.

Results

Twenty-nine pharmacists (15 at CSMC, 14 at LBMMC) participated in Phase I of the study to supply baseline data of the checking accuracy of pharmacists. A total of 41 technicians (24 at CSMC, 16 at LBMMC, and 1 working at both), three of whom were interns, participated in Phase II of the study. All 41 technicians successfully completed the didactic training, 39 successfully completed the audits and became certified checkers for Phase III, and 2 technicians (including 1 of the interns) did not complete the certification audits because they were reassigned or had resigned.

Table 1 lists the combined-institution accuracy rates of pharmacist and technician checkers in Phase I and II, respectively. For technicians, both the observed average accuracy rate and its lower confidence limit exceeded the minimum requirement of 99.8% for a certified checker. The difference in accuracy rates between pharmacists and technicians was significant ($p < 0.0001$). Interestingly, the mean accuracy rates for technicians were identical at the two institutions ($p = 1.0$). The two pharmacy interns had accuracy rates of 99.89% and 99.97%. One technician had an accuracy rate of 99.75%, which was just below the target rate, and subsequently met the minimum requirement and became certified after the next audit.

In Phase III, all certified technicians at both institutions maintained a minimum accuracy of 99.8% during their monthly and quarterly audits. Phase III began in April 1999; through December 2001, no certified technician checker had failed any quality assurance audits. However, some technicians were removed from the list of certified checkers during the study period because of work reassignments or other non-study-related issues. The board of pharmacy was continually updated on the names of certified technician checkers in the semiannual reports submitted.

Discussion

The proposition of allowing trained technicians to check unit dose medication cassettes filled by other technicians has been hotly debated in California in the past decade (appendix). This study's results appear to support the ability of well-trained technicians to accurately check unit dose medications.

Several studies have been published evaluating the accuracy of pharmacy technicians in checking other technicians in a unit dose medication fill system.⁷⁻¹³ Our results corroborate the findings from these studies; in fact, we observed a higher accuracy rate for technicians than for pharmacists ($p < 0.0001$). The boards of pharmacy in Kansas, Minnesota, and Washington currently allow technicians to check unit dose medication cassettes filled by other technicians. In addition, the American Society of Health-System Pharmacists and the

Table 1.
Accuracy of Pharmacists and Technicians in Checking Unit Dose Medication Cassettes

Checker	No. Participants	No. Doses Checked	Mean Accuracy Rate(%) ^a	95% Confidence Interval (%)
Pharmacists	29	35,829	99.52	99.44–99.58
Technicians ^b	39	161,740	99.89	99.87–99.90

^aThe difference in accuracy rates between pharmacists and technicians is significant ($p < 0.0001$), using mixed-effects logistic regression models.

^bIncludes two pharmacy interns who were employed and functioning as technicians.

California Society of Health-System Pharmacists (professional policy 9801, October 1998) support the role of the technician in checking unit dose medication cassettes.

The expansion of the technician's role has been shown to increase pharmacists' productivity.¹⁴ We estimated that pharmacists at each institution spent approximately one hour per day per pharmacist checking unit dose medication cassettes before the program was implemented. In this experimental program, the pharmacists were able to use this additional time to expand clinical services and respond to drug therapy-related requests from physicians, such as dosing recommendations. The training and auditing of technicians for checking medication cassettes are centralized and carried out by the technician supervisor, who is under the direction of a pharmacist manager. By centralizing this responsibility, decentralized pharmacists gain additional time for direct patient care activities. Also, pharmacists at both institutions have reported an increase in job satisfaction after implementing the experimental program.

When evaluating the study results, some limitations should be acknowledged. The pharmacist checkers selected to determine the baseline accuracy rate of checking unit dose medication cassettes were those who happened to be staffing the inpatient areas on the dates that the audits were performed. Neither the pharmacist checkers nor the dates of the audits were randomized. The pharmacists and the technicians were

cognizant of the study, although they did not necessarily know when audits were to be conducted. Artificial errors introduced were not randomized using a random numbers table but were based on the judgment of the pharmacist auditors who attempted to introduce a variety of different errors. The auditors at each institution introduced errors independently. In addition, the severity of errors was not defined in the study; therefore, this information was not included in the results.

The results of this study were presented to the California State Board of Pharmacy, which is now reconsidering allowing technicians to check unit dose cassettes filled by other technicians in the inpatient setting, under the same conditions of this study. The waiver for this study expires in December 2002. Until state regulations are changed or the expiration date is reached, both institutions will continue to gather data from the quarterly audits.

Conclusion

In this study, we concluded that pharmacy technicians who had been trained and certified in a closely supervised program that incorporates quality assurance mechanisms could safely and accurately check unit dose medication cassettes filled by other technicians.

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Appendix—History of California state regulations allowing technicians to check unit dose medication cassettes filled by other technicians

Year	State Regulation
Before 1993	Acute care hospitals in California were permitted to allow technicians to check the accuracy of technician-filled inpatient unit dose medication cassettes, under chart order exemption in the pharmacy regulations.
1993	The use of inpatient pharmacy technicians to check technicians filling unit dose cassettes was deemed unacceptable by the California State Board of Pharmacy, as evidenced by the following correspondence provided to the California Association of Hospital and Health Systems: "Please note the law does not authorize a technician to check another technician. While a technician may check another technician, the final check must always be done by a pharmacist."

Continued on next page

■ REPORTS Checking unit dose medication cassettes

Appendix—History of California state regulations allowing technicians to check unit dose medication cassettes filled by other technicians (*continued*)

<u>Year</u>	<u>State Regulation</u>
1994	The Hospital Pharmacy Committee of the California State Board of Pharmacy proposed draft language to add a section to the California Code of Regulation (CCR1717) to allow pharmacy technicians to check the work of other pharmacy technicians in connection with filling unit dose medication cassettes for patients whose orders had been previously reviewed by a pharmacist.
1995	This draft language was presented in May at a board of pharmacy informational hearing.
1996	<p>In June, as a result of failure to reach agreement over the proposed language, the board developed a technician committee. This committee was charged to evaluate the entire pharmacy technician program including changes necessary to improve the program, discuss and plan for future changes and roles of technicians, and pursue any statute or regulatory changes necessary to accommodate these practices.</p> <p>The committee, in an October report to the board, recommended several potential changes including asking the board to consider allowing technicians to check the work of other technicians for unit dose medication cassette filling under a waiver system that included specific provisions (e.g., functions). In response to this report, the board of pharmacy voted to move forward with regulatory action to allow technicians to check the accuracy of technicians' work in a unit dose medication cassette fill system. During this time, the board of pharmacy began to enforce the California Code of Regulations relating to the use of technicians for checking of unit dose medication cassettes and required facilities to discontinue the practice.</p>
1997	<p>In May, responding to requests from multiple health systems and the California Society of Health-System Pharmacists, the board of pharmacy gave notice of its intent to amend regulations to allow technician checking of technician-filled unit dose medication cassettes.</p> <p>All interested parties were provided an opportunity to provide oral testimony at the proposal hearing in July. At that time, the board of pharmacy did not approve moving forward with the amended regulations. In response to the many delays in reaching consensus to change current regulations, representatives from LBMMC and CSMC developed the proposal in collaboration with the University of California, San Francisco, School of Pharmacy to perform a study in order to provide the board with objective data.</p>
1998	On May 27, the board granted the requested waiver of the California Code of Regulations to conduct the "experimental program." The waiver was initially granted until November 1, 2000. However, the waiver was subsequently extended until February 1, 2001.
2001	In January, having reviewed the results of this study, the board extended the waiver until December 2002.

SPECIAL ARTICLE

Interrelationships among Mortality Rates, Drug Costs, Total Cost of Care, and Length of Stay in United States Hospitals: Summary and Recommendations for Clinical Pharmacy Services and Staffing

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We evaluated interrelationships and associations among mortality rates, drug costs, total cost of care, and length of stay in United States hospitals. Relationships between these variables and the presence of clinical pharmacy services and pharmacy staffing also were explored. A database was constructed from the 1992 American Hospital Association's Abridged Guide to the Health Care Field, the 1992 National Clinical Pharmacy Services database, and 1992 Health Care Finance Administration mortality data. A severity of illness-adjusted multiple regression analysis was employed to determine relationships and associations. Study populations ranged from 934–1029 hospitals (all hospitals for which variables could be matched). The only pharmacy variable associated with positive outcomes with all four health care outcome measures was the number of clinical pharmacists/occupied bed. That figure tended to have the greatest association (slope) with reductions in mortality rate, drug costs, and length of stay. As clinical pharmacist staffing levels increased from the tenth percentile (0.34/100 occupied beds) to the ninetieth percentile (3.23/100 occupied beds), hospital deaths declined from 113/1000 to 64/1000 admissions (43% decline). This resulted in a reduction of 395 deaths/hospital/year when clinical pharmacist staffing went from the tenth to the ninetieth percentile. This translated into a reduction of 1.09 deaths/day/hospital having clinical pharmacy staffing between these staffing levels, or \$320 of pharmacist salary cost/death averted. Three hospital pharmacy variables were associated with reduced length of stay in 1024 hospitals: drug protocol management (slope -1.30, $p=0.008$), pharmacist participation on medical rounds (slope -1.71, $p<0.001$), and number of clinical pharmacists/occupied bed (slope -26.59, $p<0.001$). As drug costs/occupied bed/year increased, severity of illness-adjusted mortality rates decreased (slope -38609852, R^2 8.2%, $p<0.0001$). As the total cost of care/occupied bed/year increased, those same mortality rates decreased (slope -5846720642, R^2 14.9%, $p<0.0001$). Seventeen clinical pharmacy services were associated with improvements in the four variables.
(Pharmacotherapy 2001;21(2):129–141)

Numerous studies reported relationships between various components of total cost of care

and mortality rates,^{1–5} but none evaluated the total cost of care in a large population of United

States hospitals. A MEDLINE search could not identify any studies in which the association between drug costs and mortality rates were explored in a large number of hospitals. In addition, no studies evaluated mortality rates, drug costs, total cost of care, and length of stay together in a large number of hospitals. We explored the interrelationships among these variables and summarized relationships between them and the presence of clinical pharmacy services and pharmacy staffing. The association between clinical pharmacy services and pharmacy staffing on length of hospital stay were explored in detail.

Data from 1992 and 1989 showed that pharmacist staffing and certain clinical pharmacy services had a direct relationship and were associated with reduced hospital mortality rates.⁶⁻⁸ In addition, increased staffing levels of clinical pharmacists and certain clinical pharmacy services had a direct relationship and were associated with reduced drug costs in U.S. hospitals.⁹ Finally, increased staff levels of pharmacy administrators and clinical pharmacists and the presence of six clinical pharmacy services had a direct relationship and were associated with reduced total cost of care.¹⁰

Length of hospital stay provides some measure of the hospital's efficiency. In addition, it is important when analyzing the hospital's profit structure. If two hospitals have the same average daily census, but one of them has a 20% shorter length of stay, that hospital would have 20% more admissions and about the same cost structure. In a capitated reimbursement model, the hospital with 20% more admissions would be able to bill for 20% more patients than the one with longer stay. Our other studies on mortality rates,⁶⁻⁸ drug costs,⁹ and total cost of care¹⁰ did not measure efficiency.

Whereas a substantial number of studies documented the benefits of pharmacists and clinical pharmacy services at individual clinical sites,¹¹⁻³⁹ only a few determined the beneficial effects of pharmacists and clinical pharmacy services on major health care outcome variables

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in a large number of hospitals.⁶⁻¹⁰ Studies of large numbers of hospitals are critical, since they are not subject to bias of patient populations, quality of health care professionals, physical facilities, structure, and process that may confound studies conducted in individual sites. In addition, when analyzed together, multihospital studies provide a road map as to which clinical pharmacy services are likely to be successful in most hospitals. This study analyzed new relationships and associations between these health outcome variables and clinical pharmacy services and pharmacy staffing. Associations between pharmacy staffing and clinical pharmacy services on length of stay are provided since these data have not been published previously.

Methods

Sources of Data

Data for 14 clinical pharmacy services and pharmacist staffing were obtained from the 1992 National Clinical Pharmacy Services database.⁴⁰ Methods of analyzing data are available elsewhere.⁴⁰⁻⁴² Mortality rate information was obtained from the Health Care Finance Administration (HCFA).⁴³ Admissions data, occupancy rates, length of stay, and total cost of care for each hospital were obtained from the American Hospital Association's (AHA) abridged guide to healthcare.⁴⁴ The National Clinical Pharmacy Services (NCPS) survey instrument was updated from previous surveys and pretested by 25 directors of pharmacy.^{41, 42} The questionnaire was mailed to the director of pharmacy in each acute care, general medical-surgical hospital listed in the AHA database.⁴⁴ Study methodology, variables, and demographic results of this study are available elsewhere.⁴⁰⁻⁴² The NCPS database is the largest hospital and clinical pharmacy database in the U.S. These databases were integrated into one database, and SAS, release 6.12, implemented on a personal computer, was used for all statistical analyses.⁴⁵ All data were for inpatients only.

The AHA listed 4822 general medical-surgical hospitals in 1992.⁴⁴ Variables from the AHA database were matched for 3444 hospitals (demographic, severity of illness) that constituted hospitals that could be included in these study populations (100%). Hospitals included in these studies had information on 14 clinical pharmacy services and pharmacist staffing from the NCPS database⁴⁰; length of stay, demographic, and severity of illness variables

from the AHA database⁴⁴; and HCFA Medicare mortality data.⁴³ Only general medical-surgical hospitals were used so as to provide more homogeneous information. Mortality rates, costs, and length of stay information for psychiatric, alcohol and drug rehabilitation, or rehabilitation hospitals would not be appropriate since they are substantially different from general medical-surgical hospitals.⁴⁴ From 1597 hospitals in the 1992 NCPS database, 3444 in the AHA database, and 4822 from HCFA, 1029 hospitals were matched for mortality data,⁸ 934 for drug cost data,⁹ 1016 for total cost of care data,¹⁰ and 1024 for length of stay data. These hospitals constituted the study populations.

Variables and Analysis

Centrally delivered clinical pharmacy services used in the analysis were drug use evaluation, in-service education, drug information, poison information, and clinical research. Patient-specific clinical pharmacy services were adverse drug reaction (ADR) monitoring, pharmacokinetic consultations, drug therapy monitoring, drug protocol management, total parenteral nutrition (TPN) team participation, drug counseling, cardiopulmonary resuscitation (CPR) team participation, medical rounds participation, and admission drug histories. We defined clinical pharmacy services specifically to indicate active participation by the pharmacist in patient care. Definitions for these clinical pharmacy services are shown in Appendix 1.

Hospital pharmacist staffing data were taken from full-time equivalent (FTE) data collected in the NCPS database survey.⁴⁰ Hospital pharmacy administrators were defined as FTE pharmacy directors, assistant directors, and supervisory pharmacists; dispensing pharmacists as FTE pharmacists who spent most of their work time (> 50%) primarily in dispensing activities; and clinical pharmacists as FTE pharmacists who spent most of their work time (> 50%) providing clinical pharmacy services (nondispensing). Each category was mutually exclusive. Staffing data were for inpatients only.

Severity of illness was controlled by forcing three variables into the multiple regression analysis model: percentage of intensive care unit (ICU) days (calculated as ICU days divided by total inpatient days), annual number of emergency room visits divided by the average daily census, and percentage of Medicaid patients (calculated as Medicaid discharges divided by

total discharges). These variables were validated as severity of illness measures in similar studies.^{1, 3, 4, 6-10, 46, 47} They were chosen because they are the only ones validated as adjusters for severity of illness using these national databases.^{1, 3, 4, 6-10, 46, 47} Other variables have been used to adjust for severity of illness with smaller patient populations (Acute Physiology and Chronic Health Evaluation [APACHE] scores, specific patient case mix, patient age, number of surgical patients, physician experience, length of shifts, patient work loads, etc.), but they were not available for the study hospitals. Diagnosis-related groups are not reliable severity of illness adjusters since many hospitals have inflated these measures.

Patient care outcome measures must adjust for patient characteristics that influence the outcome measure.⁴⁸⁻⁵⁰ If outcome measures (e.g., length of stay) do not adjust for severity of illness, conclusions for hospitals that treat severely ill patients would be inaccurate, leading to erroneous conclusions about the health care provided by professionals in these institutions.

Statistical Analyses

Severity of illness-adjusted multiple regression analysis was used. All multiple regression models (previous work,⁶⁻¹⁰ length of stay, interrelationships among mortality rates, drug costs, total cost of care, length of stay, hospital pharmacy staffing) used the severity of illness-adjusted model. For multiple regression analysis, stepwise procedures were used to select variables for the model.^{51, 52}

Severity of illness variables were forced into the multiple regression model before any other variables were allowed to enter. A weighted least squares regression was used to estimate and test relationships among hospital and pharmacy staffing, clinical pharmacy services, and mortality rates.^{7, 8} The weight used in the analysis was the inverse of the variance for the observed mortality rate, $N/[p \cdot (1 - p)]$, where N was the number of Medicare admissions to the hospital and p was HCFA's expected mortality rate for each hospital. Methods used for these mortality models are discussed in depth elsewhere.⁶⁻⁸

After forced entry of severity of illness variables, stepwise regression was used to select remaining variables. Variables selected through this method were confirmed by forward- and backward-regression techniques, both of which selected the same set of variables. The

Table 1. Summary of Significant Associations Among Clinical Pharmacy Services, Pharmacy Staffing, and Mortality Rates, Drug Costs, Total Cost of Care, and Length of Stay

	Mortality Rate ⁸ (1029 hospitals)		Drug Costs ⁹ (934 hospitals)		Total Cost of Care ¹⁰ (1016 hospitals)		Length of Stay (1024 hospitals)	
	Slope	p Value	Slope	p Value	Slope	p Value	Slope	p Value
Central clinical pharmacy services								
Drug-use evaluation					-34871	0.001		
In-service education			-1148	0.016				
Drug information	-0.002	0.043	-1090	0.015	-11749402	0.003		
Poison information								
Clinical research	-0.008	0.0001			42922279	0.0001		
Patient-specific clinical pharmacy services								
ADR monitoring					-6599253	0.008		
Pharmacokinetic consultations								
Drug therapy monitoring								
Drug protocol management			-1065	0.049	-17423551	0.001	-1.30	0.008
TPN team participation					10789291	0.001		
Drug counseling								
CPR team participation	-0.002	0.039						
Medical rounds participation					-4770426	0.0001	-1.71	0.001
Admission drug histories	-0.006	0.005	-1450	0.011	-6106570	0.017		
Pharmacy staffing/occupied beds								
All pharmacists	-0.0381	0.0185						
Pharmacy administrators	X ^a	X ^a	46442	0.0001	-324890768	0.0001		
Dispensing pharmacists	X ^a	X ^a	53299	0.0001	120000000	0.006		
Clinical pharmacists	X ^a	X ^a	-21809	0.018	-38864012	0.007	-26.59	0.001
Pharmacy technicians	X ^a	X ^a	54915	0.0001				
R ² (actual)	22.4%		15.3%		48.9%		11.4%	

^aNot determined as part of the original analysis. See Table 4 for specific information on pharmacy staffing and mortality rates.

correlation matrix for independent variables and variance inflation factor were used to examine possible effects of multicollinearities for the length of stay analysis.⁴⁵ These indicated that there were no apparent problems among the set of independent variables.

We used severity of illness multiple regression analysis to determine interrelationships among mortality rates, drug costs, total cost of care, and length of stay. These relationships are reported as slope, R², and significance. Slope measures the rate of change for the variable and is expressed as either positive (e.g., as drug costs increased, total cost of care increased) or negative (e.g., as drug costs increased, mortality rates decreased). A higher slope indicated that changes in that variable were associated with greater changes in the other variable (e.g., changes in the number of clinical pharmacists/occupied bed were associated with greater changes in mortality rates than other pharmacy variables). In addition, multiple regression analysis allowed us to determine direct relationships and associations between clinical pharmacy services and pharmacist staffing variables and mortality rates, drug costs, total cost of care, and length of stay in

U.S. hospitals.

A comparison of clinical pharmacy services and pharmacy staffing variables that was statistically significant in the multiple regression model for length of stay was developed further. The difference in the length of stay, based on whether the hospital provided the clinical pharmacy service, was determined. Each pharmacy staffing variable was analyzed in a separate multiple regression model that included mortality rates and the severity of illness variables. The a priori level of significance for all tests was set at 0.05.

Results

Length of Stay

A total of 1024 hospitals (64%) of the 1597 general medical-surgical hospitals from the 1992 NCPS database were matched from the 3444 hospitals from the AHA database (potential pool of study hospitals) for length of stay data. These 1024 hospitals constituted the study population. The mean length of stay for each patient admission was 7.12 ± 14.02 days, 55,586 ± 52,190 patient-days/hospital/year, and

Table 2. Summary of Significant Associations Between Clinical Pharmacy Services and Lower Number of Deaths, Drug Costs, and Total Cost of Care

	Lower Deaths (actual) ^a (1029 hospitals)		Lower Drug Costs (\$) ^a (934 hospitals)		Total Cost of Care (\$) (increase or reduction) ¹⁰ (1016 hospitals)	
	Per Hospital	All Hospitals ^a	Per Hospital	All Hospitals ^a	Per Hospital	All Hospitals ^a
Central clinical pharmacy services						
Drug use evaluation					1,119,810	1,005,589,542
In-service education			77,879	48,518,735		
Drug information	3.89	10,463	430,580	90,852,346	5,226,128	1,212,461,747
Poison information						
Clinical research	11.63	21,125			(9,558,788) ^b	(1,013,231,529) ^b
Patient-specific clinical pharmacy services						
ADR monitoring					1,610,841	1,101,815,258
Pharmacokinetic consultations						
Drug therapy monitoring						
Drug protocol management			137,334	45,045,444	1,729,608	614,010,986
TPN team participation					(3,211,355) ^b	(1,027,633,638) ^b
Drug counseling						
CPR team participation	2.1	5047				
Medical rounds participation					7,979,721	1,212,917,508
Admission drug histories	8.61	3843	213,388	5,548,094	6,964,145	208,924,355

^aAll hospitals that offer the service.^bIncrease in total costs associated with these services.

57,198,012 patient-days/year for all study hospitals/year (41% of total patient-days for all U.S. hospitals).⁵³ The mean total cost/patient-day was \$933 ± \$428. The mean number of admissions/year was 8061.39 ± 6721.89 admissions/hospital or 8,254,883³⁶ total admissions (34% of all admissions). The average daily census (ADC) for study hospitals was 152.32 ± 143.28 patients/day. Study populations (pool of all U.S. hospitals available for analysis from HCFA and AHA)^{43, 44} for this and our previous studies represent 3763 hospitals for hospital staffing and mortality rates (78% of all hospitals)⁷; 1029 hospitals for clinical pharmacy services and mortality rates (31% of all hospitals)⁸; 934 hospitals for clinical pharmacy services and drug costs (25% of all hospitals)⁹; 1016 hospitals for clinical pharmacy services, staffing, and total cost of care (30% of all hospitals)¹⁰; and 1024 hospitals for length of stay (30% of all hospitals).

Table 1 shows associations among mortality rates, drug costs, and total cost of care, length of stay, and clinical pharmacy services and hospital staffing. Two services were associated with reduced length of stay: drug protocol management and pharmacist participation on medical rounds. The number of clinical pharmacists/occupied bed tended to have the greatest association (slope) with reductions in

length of stay. The R² for the length of stay regression model was 11.4% and the adjusted R² was 10.8%. Table 2 presents information on clinical pharmacy services: deaths/hospital and for all hospitals offering the service,⁸ drug cost reductions/hospital and for all hospitals offering the service,⁹ and total cost of care increases or decreases for each hospital and all hospitals offering the service.¹⁰ Table 3 shows reductions in length of stay for hospitals that have pharmacist-provided drug protocol management and pharmacist participation on medical rounds (from the length of stay multiple regression model). Figure 1 shows the relationship between mean length of stay/hospital and staffing level of clinical pharmacists (graphed as quintiles: tenth, thirtieth, fiftieth, seventieth, and ninetieth percentiles).

Interrelationships among Health Care Outcome Variables

As drug costs/occupied bed increased, severity of illness-adjusted mortality rates decreased (slope -38609852, actual R² 8.2%, adjusted R² 7.6%, p<0.0001). This relationship is shown graphically in Figure 2 as death rate/1000 admissions and drug costs/occupied bed/year (quintiles). As the total cost of care/occupied bed increased, severity of illness-adjusted

Table 3. Length of Stay for Hospitals with Clinical Pharmacy Services Associated with Significantly Shorter Length of Stay in the Multiple Regression Model

Services Associated with Reduced Length of Stay	No. (%) of Hospitals Providing the Service	Mean Reduction in Length of Stay/Patient in Hospitals Offering the Service	Total No. of Patient Days Reduced/Hospital Offering the Service	Total No. of Patient Days Reduced for All Hospitals Offering the Service
Drug protocol management	354 (34.6)	1.22 ± 0.91	432.67 ± 167.93	152,998.80
Medical rounds participation	153 (14.8)	1.34 ± 0.93	164.82 ± 88.51	25,178.46

Table 4. Relationships between Hospital Pharmacy Staffing and Severity of Illness-Adjusted Mortality Rates

Types of Hospital Pharmacy Staff	Slope	R ²		Significance
		Actual (%)	Adjusted (%)	
All pharmacists	-0.101710	4.5	4.1	0.0001
Pharmacy administrators	0.190177	3.4	3.2	0.0001
Dispensing pharmacists	-0.091700	3.6	3.3	0.0001
Clinical pharmacists	-0.408114	10.1	9.8	0.0001
Pharmacy technicians	-0.097564	3.2	2.8	0.0001

mortality rate decreased (slope -5846720642, actual R² 14.9%, adjusted R² 14.1%, p<0.0001; Figure 3). As drug costs/occupied bed increased, the total cost of care increased (slope 18.989, actual R² 11.5%, adjusted R² 10.7%, p<0.0001). These were the only statistically significant associations among severity of illness-adjusted mortality rates, drug costs, total cost of care, and length of stay.

Clinical Pharmacy Services, Hospital Pharmacy Staffing, and Mortality Rate, Drug Costs, and Total Cost of Care

Figure 4 (quintiles), taken from published data but not graphed,⁸ shows the relationship between number of pharmacists/100 occupied beds and

number of deaths/hospital. The difference between the highest number of deaths/hospital (thirtieth percentile) and lowest number of deaths/hospital (ninetieth percentile) was 264 deaths, a 36% reduction from the 729 deaths/hospital in the thirtieth percentile. Table 4 presents severity of illness-adjusted multiple regression data for hospital pharmacy staffing categories. As the number of pharmacy administrators increased, mortality rates increased. As the number of dispensing pharmacists, clinical pharmacists, and technicians increased, mortality rates decreased. The number of clinical pharmacists/occupied bed tended to have the greatest association (slope) with reductions in mortality rates (Figure 5).

The only pharmacy variable that was

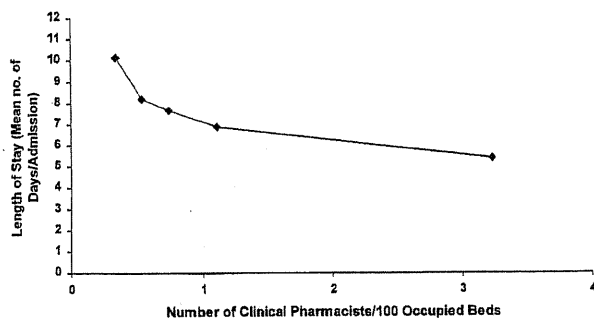


Figure 1. Clinical pharmacist staffing and length of hospital stay.

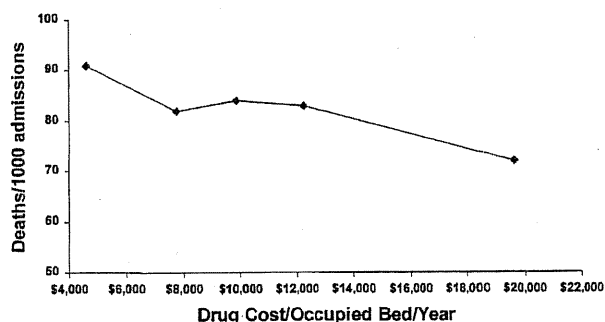


Figure 2. Hospital deaths/1000 admissions and drug costs.

associated with positive outcomes with all four outcome measures was the number of clinical pharmacists/occupied bed. This tended to have the greatest association (slope) with reductions in mortality rate, drug costs, and length of stay. It also had the second highest association (slope) with reductions in total cost of care. No individual clinical pharmacy service was associated with all four outcome measures. Three services were associated with three outcome measures: pharmacist-provided drug information, drug protocol management, and admission drug histories. Pharmacist participation on medical rounds was associated with improvements with two outcome measures, total cost of care and length of stay. Five services were associated with improvements with one outcome measure: drug use review, in-service education, clinical research, ADR monitoring, and CPR team participation. Pharmacist-provided drug information, drug protocol management, and admission drug histories were associated with reductions in both drug costs and total cost of care. Pharmacist-provided clinical research and participation on the TPN team were associated with increased total cost of care.

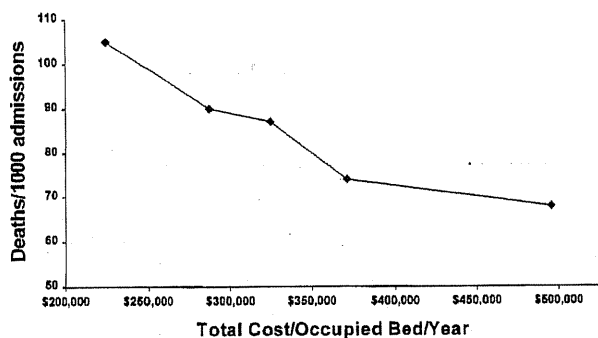


Figure 3. Hospital deaths/1000 admissions and total cost of care.

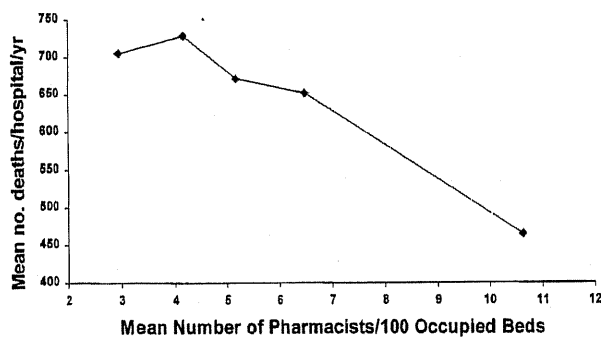


Figure 4. Pharmacist staffing and deaths/hospital.

Discussion

Length of Stay

Reasons why pharmacist-provided drug protocol management was associated with shorter length of stay are unknown. Perhaps the service provides quality control for therapy. Ensuring the quality of drug therapy may increase the efficiency and quality of patient care, which can be measured as shorter length of stay. Length of stay is a strong predictor of hospitals' quality and efficiency of care.^{54, 55} Inappropriate drug prescribing is associated with increased length of stay.^{23, 24} There were 432.76 fewer patient-days/hospital associated with the presence of pharmacist-provided drug protocol management, a decrease of 152,998.80 patient-days for the 354 hospitals having this service. A potential reduction of 442,572.80 patient-days (1% of total patient-days for all 1024 hospitals) could be realized if all 1024 hospitals had this service. The median pharmacist salary cost/hospital/year for providing drug protocol management was \$1650, or \$3.81 of pharmacist salary cost/patient-day saved.⁵⁶ Every dollar of pharmacist salary cost was associated with a reduction of \$244.88 in length of stay savings (\$933 cost/day divided by \$3.81), or a 1:244.88 ratio. This service was associated with substantial reductions in cost of care and probable increased profitability for hospitals having pharmacists perform drug protocol management. The service was probably an indicator of hospitals' efficiency and quality of care.

Reasons why pharmacists' participation on medical rounds was associated with shorter length of stay also are unknown. Since medical rounds are where most decisions are made about patient care, perhaps pharmacists influence drug

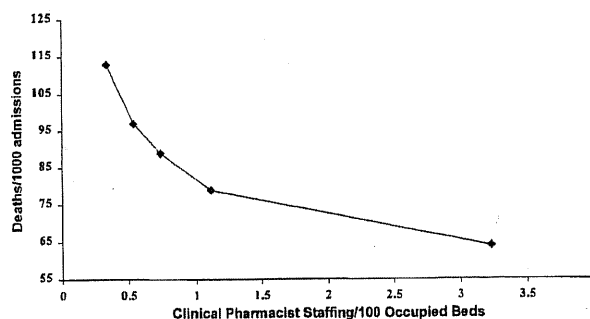


Figure 5. Clinical pharmacist staffing and hospital deaths/1000 admissions.

therapy decisions and reduce risks of adverse drug events. Other investigators also found this result associated with placing clinical pharmacists on rounds in individual hospitals.^{26, 27, 57-59} Our data clearly confirm the finding. There were 164.82 fewer patient-days/hospital associated with the presence of pharmacist participation on medical rounds, a decrease of 25,178.46 patient-days in the 153 hospitals having the service. A potential reduction of 168,514.65 patient-days (0.3% of the total patient-days for all 1024 hospitals) could be realized if all 1024 hospitals had this service. The median pharmacist salary cost/hospital for pharmacists attending medical rounds was \$31,652/year, or \$192.04 of pharmacist salary cost/patient-day saved.⁵⁶ Every dollar of pharmacist salary cost was associated with a reduction of \$4.86 in length of stay savings (\$933 cost/day divided by \$192.04), or a 1:4.86 ratio. This service was associated with substantial reductions in cost of care and probable increased profitability for hospitals having pharmacists on medical rounds. It is probably an indicator of hospitals' efficiency and quality of care.

As clinical pharmacist staffing increased from the tenth percentile (0.34/100 occupied beds) to the ninetieth percentile (3.23/100 occupied beds), mean length of stay fell from 10.17 to 5.39 days/patient, a difference of 4.78 days/patient or a 47% reduction. The number of clinical pharmacists/occupied bed tended to have the greatest association (slope) with reductions in length of stay. It was the best predictor of all pharmacy variables for shorter length of stay in study hospitals.

Interrelationships between Health Care Outcome Measures

The relationship between the severity of illness-adjusted death rate/admission and drug costs/occupied bed (slope -38609852, R^2 8.2%, $p < 0.0001$) is rather striking. As drug costs increased from the tenth (\$4623) to the ninetieth percentile (\$19,628)/occupied bed/year, the death rate declined from 91/1000 to 72/1000 admissions, a 21% decline. With 8061.39 ± 6721.89 admissions/hospital/year, this translates into a difference of 153 deaths/hospital having drug spending between the tenth and ninetieth percentiles. This translates into a reduction of 0.42 deaths/day/hospital between these drug cost levels. If these differences in deaths were extrapolated to all study hospitals, the number of

lives saved associated with increased drug costs could be substantial. The drug cost/death difference between hospitals spending at the tenth and ninetieth percentiles was \$14,938/death (\$15,005 difference in drug costs/occupied bed/year {tenth–ninetieth percentiles} divided by 153 deaths \times 152.32 {ADC}). Since mortality rates are a very good indicator of the quality of care,^{3, 4, 42, 48, 49} it appears that higher drug costs predict better patient care.

Reasons for findings between drug costs and mortality rates are not known. The relationship between higher drug costs and lower mortality rates suggests that newer more costly drugs may be better than older less expensive ones in reducing deaths. This is not to suggest that indiscriminate use of drugs is appropriate, but health care outcomes must be considered and measured when cost cutting is pursued. This finding suggests that restricting or rationing drugs based on cost alone may be detrimental to patient care. These data clearly indicate that costs and outcomes are associated in a manner that is somewhat unexpected. In the future, pharmacists must focus not only on costs, but also on health care outcome measures. Otherwise, in an effort to reduce costs, we may adversely affect an important health outcome and harm patients.

The relationship between the severity of illness-adjusted death rate/admission and total cost of care/occupied bed (slope -5846720642, R^2 14.9%, $p < 0.0001$) is impressive. As total costs increased from the tenth (\$287,205) to the ninetieth percentile (\$495,305)/occupied bed/year, the death rate declined from 105/1000 to 68/1000 admissions (35% decline). With 8061.39 ± 6721.89 admissions/hospital/year, this translates into a difference of 298 deaths/hospital having total spending between the tenth and ninetieth percentiles. This translates into a reduction of 0.82 deaths/day/hospital between these total cost of care levels. If these differences in deaths were extrapolated to all study hospitals, the number of lives saved associated with increased total cost of care could be substantial. The total cost/death difference between hospitals spending at the tenth and ninetieth percentiles was \$106,368/death (\$208,100 difference in total costs/occupied bed/year {tenth–ninetieth percentile} divided by 298 deaths \times 152.32 {ADC}). Since mortality rates are a very good indicator of quality of care,^{3, 4, 42, 48, 49} it appears that higher hospital costs predict better patient care. This suggests that indiscriminate cost

cutting in the hospital (staff or supplies) may be deleterious to patient care.

Reasons for findings between total cost of care and mortality rates are unknown. This relationship is not unexpected, since the largest component of a hospital's cost structure is personnel, and increased staffing levels of medical residents, registered nurses, pharmacists, medical technologists, and total hospital personnel are associated with lower mortality rates.⁷ The relationship between drug costs and total cost of care (slope 18.99, R^2 11.5%, $p < 0.0001$) seems logical, since drug costs are a component of total hospital costs.

Clinical Pharmacy Services, Hospital Pharmacy Staffing, and Mortality Rates, Drug Costs, and Total Cost of Care

Discussion regarding mortality rates, drug costs, total cost of care, and clinical pharmacy services and hospital pharmacy staffing variables are available elsewhere.⁷⁻¹⁰ Relationships between the severity of illness-adjusted death rate/admission and clinical pharmacist staffing/occupied bed (slope -0.408114, R^2 10.1%, $p < 0.0001$) are striking. As clinical pharmacist staffing levels increased from the tenth (0.34/100 occupied beds) to the ninetieth percentile (3.23/100 occupied beds), hospital deaths declined from 113/1000 to 64/1000 admissions (43% decline). With 8061.39 \pm 6721.89 admissions/hospital/year, this translates into a difference of 395 deaths/hospital having clinical pharmacist staffing between the tenth and ninetieth percentiles. This translates into a reduction of 1.09 deaths/day/hospital between these staffing levels. If these differences in deaths were extrapolated to all study hospitals, the number of lives saved associated with increased clinical pharmacist staffing could be substantial. The clinical pharmacist staffing/100 occupied beds/death difference between hospitals staffing clinical pharmacists at the tenth and ninetieth percentiles was 0.0073 FTE clinical pharmacist/death (2.89 FTE clinical pharmacist {tenth-ninetieth percentile} divided by 395 deaths). The 1992 mean pharmacist salary for hospital pharmacists was \$43,791 \pm 12,206.⁵⁶ The total pharmacist salary cost/death difference between hospitals having clinical pharmacist staffing at the tenth and ninetieth percentiles was \$320 (\$43,791 \pm 12,206 \times 0.0073). Since mortality rates are a very good indicator of quality of care,^{3, 4, 42, 48, 49} it appears that higher

staffing levels of clinical pharmacists predict better patient care.

One of the more disturbing aspects of associations between hospital pharmacy staffing and severity of illness-adjusted mortality rates is the increased death rate associated with increased staffing of hospital pharmacy administrators. This is consistent with what we reported previously with hospital administrators.⁷ Given the administrative inefficiency of our health care system,⁶⁰ high hospital administrative costs (accounting for 26% of total hospital costs),⁶¹ and this association with mortality rates, it may be prudent to limit the number of hospital pharmacy administrative personnel. In addition, further study seems warranted to determine specific reasons why increased staffing levels of hospital administrators and hospital pharmacy administrators are associated with increased mortality.

With the exception of clinical pharmacists, staffing levels of pharmacy administrators, dispensing pharmacists, and pharmacy technicians have both positive and negative associations with health care outcome measures. Increased hospital pharmacy administrative staffing was associated with increased mortality rates and increased drug costs, but decreased total cost of care. Increased dispensing pharmacist staffing was associated with reduced mortality rates, but increased drug costs and increased total cost of care. Increased pharmacy technician staffing was associated with decreased mortality rates, but increased drug costs. In contrast, increased clinical pharmacist staffing was uniformly associated with reduced mortality rates, decreased drug costs, decreased total cost of care, and shorter length of stay. If we are to effect major health care outcome measures and reduce costs, it appears that we should significantly increase clinical pharmacist staffing and reduce pharmacy administrator and dispensing pharmacist staffing. This recommendation takes on added importance considering that only 11% of pharmacy staffing in 1992 was allocated to clinical pharmacists.⁶² We believe the results of our previous studies⁷⁻¹⁰ and this study are conclusive with respect to hospital pharmacy staffing. The path is clear, and the profession should not continue to spend most of its personnel resources on the distribution system and administrative personnel. A paradigm shift must occur in organized pharmacy if we are to improve health care outcomes and maximize our ability to reduce

health care costs.

The beneficial results of clinical pharmacists and clinical pharmacy services are unequivocal given the data presented. These findings are remarkable since they were evident about 25 years after the first clinical pharmacists began to appear in the nation's hospitals. It is clear that clinical pharmacists are associated with improvements in the study's four outcome measures. It is less clear what specific clinical pharmacy services conclusively produce benefits with all of these health care outcomes. This is not surprising, since clinical pharmacists have been practicing only for a little over 3 decades. Clinical pharmacy is now in a phase where services are still being solidified. Standard practice methodology is not fully accepted or available in many hospitals. It may take another generation before specific clinical pharmacy services are common expectations of care in the nation's hospitals. Although the journey is not completed, we are well along the road to improving patient care. The results of our five studies unequivocally show that pharmacists, by providing clinical pharmacy services, have a bright future in health care. To make optimum contributions, we must leave the dispensing and administrative modes and provide direct patient care. It is our hope that pharmacists use these data to complete the work that the first clinical pharmacists began in the 1960s and 1970s.

Specific Recommendations

Hospital Pharmacy Staffing

Data from our five studies unequivocally show that the best way for the profession to improve patient care and reduce costs is to increase staffing levels of clinical pharmacists. Given the mixed results with hospital pharmacy administrators and dispensing pharmacists, staffing levels for these types of pharmacists should be decreased. Priority should be given to reducing pharmacists' dispensing and administrative time and increasing the level of clinical services provided to patients.

Clinical Pharmacy Services

Strong consideration should be given to having drug histories, drug information, and drug protocol management services as part of core clinical pharmacy services for most hospitals. These services were associated with positive outcomes with three of the four health care

outcome measures. Including medical rounds into the service core mix may be considered since this service was associated with improvements with two health care outcome measures. No clear picture emerges on the remaining clinical pharmacy services. However, regardless of services provided, staffing of clinical pharmacists was the best indicator of improved patient care outcomes and reduced costs. Given staffing levels for pharmacy in U.S. hospitals, it is likely that specific populations of patients must be identified to receive clinical pharmacy services.⁶²

Cost Savings

Given the relationship between drug costs, total cost of care, and mortality rates, it seems prudent to suggest that cost-cutting initiatives should include appropriate health care outcome variables (mortality rates, length of stays, etc.). If we do not include these measures when implementing initiatives, we ultimately may decrease the quality of care and harm patients. Any measures that cut costs should have an appropriate monitoring period that includes assessment of both costs and patient care outcomes. These results clearly show that reduced drug costs and reduced total cost of care can affect patients in a negative way. We must remember that the guiding principle of patient care is first to do no harm.

Limitations

Mortality rates, drug costs, total cost of care, and length of stay information is from 1992 and does not reflect the current year. Annual inflation rates and annual drug cost inflation rates of 20% would have to be considered to interpret these dollar figures in terms of current costs.⁶² Similarly, the data do not reflect changes that have occurred in the health care delivery and reimbursement system since 1992. It is possible that information provided to the AHA by hospitals and provided to us for the NCPS database were inaccurate. We did not attempt to verify the information. The total variance explained by our five regression models was consistent with other studies.^{2-4, 50, 63, 64} Since these studies were among the first to compare clinical pharmacy services, pharmacist staffing, and major health care outcome measures in a large number of U.S. hospitals, the findings have to be replicated in future studies. It is possible that the hospitals in our study population were not representative of all U.S. hospitals. However,

this is doubtful because they represent 25–78% of all hospitals^{7–10} available from HCFA and the AHA for possible study.^{43, 44} This study design allowed us to determine direct relationships between variables, but it did not allow us to determine causality. We were able to obtain only information about clinical pharmacy services. Information about services of other health care professionals, hospital structure, process, or other variables that could affect these outcome measures could not be obtained or evaluated. If these data were available, it is possible that they could affect our findings. Therefore, these findings should not be construed as cause and effect. Caution should be employed in applying our findings to individual hospitals.

Summary

These five studies clearly support the role of clinical pharmacists and clinical pharmacy services in caring for patients in the nation's

hospitals. Increased staffing levels of clinical pharmacists were associated with improvements in all four health care outcome measures. The number of clinical pharmacists/occupied bed tended to have the greatest association with reductions in mortality rate, drug costs, and length of stay. Given positive and negative findings with hospital pharmacy administrator and dispensing pharmacist staffing and outcome measures, it appears that the best way to improve patient care and reduce costs is to increase staffing levels of clinical pharmacists and promote clinical pharmacy services that these pharmacists perform. Seventeen clinical pharmacy services were associated with improvements in mortality rates, drug costs, total cost of care, and length of stay in U.S. hospitals. It is our hope that pharmacists use the results of these five studies to continue the development of clinical pharmacy. We must establish a common set of services to provide to patients.

Appendix 1. Definitions of Clinical Pharmacy Services

Central Clinical Pharmacy Services

Drug use evaluation: check if at minimum drug use patterns are analyzed and results are reported to hospital committee.

In-service education: pharmacist presents continuing education to fellow employees (M.D., R.N., R.Ph., etc.) on a scheduled basis at least 4 times/year.

Drug information: provided only if a formal drug information service with specifically assigned pharmacist(s) is available for questions. Does not require a physical location called drug information center.

Poison information: provided only if a pharmacist is available to answer toxicity and overdose questions on a routine basis with appropriate resources.

Clinical research: performed by pharmacists either as a principal investigator or coinvestigator, or pharmacist is likely to be (co)author of a published paper. Do not check if activity is limited to investigational drug distribution or record keeping.

Patient-Specific Clinical Pharmacy Services

ADR management: pharmacist evaluates potential adverse drug reaction while the patient is hospitalized and appropriately follows through with physicians.

Pharmacokinetic consultation: provided only if at a minimum the drug regimen, serum levels, and patient's medical record are reviewed and verbal or written follow-up is provided when necessary.

Drug therapy monitoring: provided only if a patient's medical record is reviewed and verbal or written follow-up is provided when necessary. Monitoring is continuing and repeated, often on daily basis. Do not check if only drug orders are reviewed. Does not include pharmacokinetic consults, TPN team, rounds, ADR management, or drug therapy protocol management.

Drug protocol management: pharmacist, under the order of a prescriber, requests laboratory tests as necessary and initiates or adjusts drug dosage to obtain the desired therapeutic outcome (e.g., aminoglycoside or heparin dosing per pharmacy).

TPN team participation: pharmacist at a minimum reviews medical records and/or provides written or verbal follow-up if required.

Drug counseling: pharmacist provides counseling on drugs either during hospitalizations or at discharge. Do not check if counseling involves solely review of label directions.

CPR team participation: pharmacist is an active member of the CPR team, attending most arrests when present in the hospital.

Medical rounds participation: pharmacist rounds with medical team at least 3 days/week actively providing specific input.

Admission drug histories: pharmacist provides admission histories.

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Pharmacist Participation on Physician Rounds and Adverse Drug Events in the
Intensive Care Unit
[Caring For The Critically Ill Patient]

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Abstract

Context: Pharmacist review of medication orders in the intensive care unit (ICU) has been shown to prevent errors, and pharmacist consultation has reduced drug costs. However, whether pharmacist participation in the ICU at the time of drug prescribing reduces adverse events has not been studied.

Objective: To measure the effect of pharmacist participation on medical rounds in the ICU on the rate of preventable adverse drug events (ADEs) caused by ordering errors.

Design: Before-after comparison between phase 1 (baseline) and phase 2 (after intervention implemented) and phase 2 comparison with a control unit that did not receive the intervention.

Setting: A medical ICU (study unit) and a coronary care unit (control unit) in a large urban teaching hospital.

Patients: Seventy-five patients randomly selected from each of 3 groups: all admissions to the study unit from February 1, 1993, through July 31, 1993 (baseline) and all admissions to the study unit (postintervention) and control unit from October 1, 1994, through July 7, 1995. In addition, 50 patients were selected at random from the control unit during the baseline period.

: A senior pharmacist made rounds with the ICU team and remained in the ICU for consultation in the morning, and was available on call throughout the day.

Main Outcome Measures: Preventable ADEs due to ordering (prescribing) errors and the number, type, and acceptance of interventions made by the pharmacist. Preventable ADEs were identified by review of medical records of the randomly selected patients during both preintervention and postintervention phases. Pharmacists recorded all recommendations, which were then analyzed by type and acceptance.

• The rate of preventable ordering ADEs decreased by 66% from 10.4 per 1000 patient-days (95% confidence interval [CI], 7-14) before the intervention to 3.5 (95% CI, 1-5; P

Conclusions: The presence of a pharmacist on rounds as a full member of the patient care team in a medical ICU was associated with a substantially lower rate of ADEs caused by prescribing errors. Nearly all the changes were readily accepted by physicians.

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In traditional hospital practice most of the burden of drug therapy decision making falls on the physician. However, studies have shown that physicians sometimes make errors in prescribing drugs. [1,2] While most errors are harmless or are intercepted, some result in adverse drug events (ADEs). The pharmacist's role in prescribing is typically reactive: responding to prescription errors long after the decision has been made for patients about whom he or she has little direct clinical knowledge. Thus, the specialized knowledge of the pharmacist is not utilized when it would be most useful: at the time of ordering.

Studies show that pharmacist retrospective review of medication orders prevents errors. [3-5] However, the pharmacist's impact might be substantially greater if he or she could provide input earlier, at the time of prescribing. It has been shown that pharmacist consultation with physicians and others in an intensive care unit (ICU) resulted in a net saving from reduced drug use of \$10,011 in a 3-month period. [6] However, we know of no controlled studies that have evaluated the effect of pharmacist participation on the key outcome measure of

error prevention-the rate of ADEs.

For these reasons, we conducted a controlled clinical trial of the efficacy of pharmacist participation in physician rounds in a medical ICU as part of a continuing study of systems changes to prevent ADEs. The ADE rate is higher among patients in ICUs, both because they have pathophysiological abnormalities and often receive many drugs.

We asked the following questions: (1) Is pharmacist participation on rounds associated with a reduction in the rate of preventable ADEs? (2) What types of interventions does the pharmacist make? and (3) Is pharmacist participation on ICU rounds accepted by physicians and nurses?

METHODS

The study was carried out in 2 medical ICUs at Massachusetts General Hospital, a large tertiary care hospital in Boston, during 2 periods: February 1, 1993, through July 31, 1993 (phase 1, preintervention), and October 1, 1994, through July 7, 1995 (phase 2, postintervention).

The study unit was a 17-bed medical ICU and the control unit was a 15-bed coronary care unit (CCU). The average daily census was 13.9 in the medical ICU and 12.9 in the CCU during phase 1 and 12.4 and 11.9, respectively, during phase 2. Nurse and physician staffing ratios were similar in the 2 units. Patients in the medical ICU had a range of acute and chronic medical illness other than primary cardiac disease, while those in the CCU were primarily cardiac patients. Each unit frequently admitted both categories of patients when the other unit was full. Patients receiving ventilatory support constituted 70% of patients in the medical ICU and 60% of patients in the CCU.

Sample

We compared outcomes in the study unit before and after the intervention, and between the study unit and a control unit during the same period after the intervention. Using a random number generator, we selected 75 patients from each of 3 groups: all patients admitted to the study unit during phase 1 and phase 2 and all patients admitted to the control unit during phase 2. To detect whether unmeasured variables may have altered the rate of ADEs (secular trend), we also randomly selected 50 patients from all those admitted to the control unit during phase 1.

The intervention was the assignment of an experienced senior pharmacist to make rounds with the patient care team in the study ICU. The pharmacist made rounds with the residents, nurses, and attending staff each morning, was present in the unit for consultation and assistance to the nursing staff during the rest of the morning, and was available on call as necessary throughout the day. The total commitment was approximately half of the pharmacist's time. In the control ICU, as is the usual practice, another pharmacist was available in the unit for part of the day but did not make rounds with physicians and nurses. The intervention began in May 1994. Data collection began in October 1994 and continued through July 1995.

Outcome Measures

We assessed the effect of pharmacist participation with 2 measures: (1) the change in the rate of preventable ADEs in the ordering stage and (2) the number and acceptance of interventions recommended by the pharmacist. We defined an ADE as an injury related to the use of a medication. A preventable ADE is an injury caused by an error in the use of a medication (eg, hypotension or hypoglycemia, changes in mental status, bleeding, or cardiac arrest). [1]

Adverse Drug Events

Using previously described methods, [7] trained and experienced investigators (1 nurse and 1 pharmacist) identified incidents (apparent medication errors or ADEs) by review of medical records in which they examined all progress notes, orders, and laboratory results during the index admission.

Incidents were evaluated independently by 2 physician reviewers, (L.L.L. and D.W.B.) who classified them according to whether or not an ADE or potential ADE was present. Using pre-established criteria, [7] they also made judgments of severity, preventability, and, if an error was present, the type of error and the stage in the process at which the error occurred. When there were disagreements the reviewers met and reached consensus. If consensus could not be reached, a third reviewer evaluated the incident. Reliability for these judgments has previously been reported [7] (for judgments about whether an incident was an ADE, kappa=0.81-0.98; for preventability, kappa=0.92; and for severity, kappa=0.32-0.37). All reviewers and investigators were blinded to patient group assignment.

Pharmacist Interventions

To develop descriptive information about changes suggested by the pharmacist, we measured the number of interventions, the type of intervention, and the percentage of recommendations accepted. For this purpose, the pharmacist completed a report form for each intervention that could potentially lead to a change in orders, noting the date, drug, nature of the order, the specific recommendation, and whether or not it was accepted by the physicians. The type of intervention was then classified as shown in (Table 1). The pharmacist also recorded events that did not involve order changes, such as errors in the pharmacy system or identification of ADEs.

Table 1. Pharmacist Interventions

Analysis

The primary measure used to assess the effect of the interventions was the rate of preventable ADEs due to prescribing errors. We conducted comparisons at 2 points in time in the study unit, before and after the intervention, and between the study and control units after the intervention.

For the before-after evaluation, we compared the rate of occurrence of preventable ordering ADEs among patients in the study unit during phase 1 with the rate in the same unit during phase 2. For the between-unit comparison, we compared the rate in the study unit during phase 2 with the rate of occurrence in the control unit in phase 2. To assess potential secular trends, we also compared the rate in the control unit in phase 1 with its rate in phase 2.

Comparisons between rates in phases 1 and 2 in the study unit (before and after) and between the study unit and the control unit in phase 2 (contemporaneous) were made using unpaired t tests. Analyses were performed using SAS statistical software. [8]

RESULTS

ADE Rates

The overall rates, expressed as preventable ordering ADEs per 1000 patient-days, are shown for both phases for both units in (Table 2). In the before and after comparison, the rate of preventable ordering ADEs per 1000 patient-days decreased in the study unit by 66% from phase 1 to phase 2 (10.4 [95% CI, 7-14] to 3.5 [95% CI, 1-5]; P

Table 2. Adverse Drug Event Rates*

When the intervention unit was compared with the control unit during the same time period (phase 2), the rate of preventable ordering ADEs in the study unit was 72% lower than in the control unit (3.5 [95% CI, 1-5] vs 12.4 [95% CI, 8-17] per 1000 patient-days; P

When results were calculated in terms of number of patients (admissions), the differences in rates were similar: in the study unit, the rate of preventable ordering ADEs decreased by two thirds, from 12% in phase 1 to 4% in phase 2, while it was essentially unchanged in the control unit (10% to 11%).

The rate of all ADEs also decreased substantially in the study unit from phase 1 to phase 2 (33.0 [95% CI, 27-39] to 11.6 [95% CI, 8-15]; P

Pharmacist Interventions

During phase 2, a total of 398 pharmacist interventions were recorded (Table 1). Of these, 366 were related to ordering, of which 362 (99%) were accepted by the physicians. Nearly half (178/389 [46%]) were pharmacist-initiated clarification or correction of a proposed or previous order. These errors included incomplete orders, wrong dose, wrong frequency, inappropriate choice, and duplicate therapy. Examples were a recommendation to reduce the dose of intravenous phenytoin from 300 mg 3 times per day, the correct oral dose, to 100 mg 3 times per day and reduction of the dose of ampicillin administered to a patient with renal failure.

In 100 instances, the pharmacist provided drug use information, most often at the time the decision was being made about whether to order a drug. Examples were education of the house staff on the selection of sedatives in patients receiving ventilatory support and the risk of extrapyramidal adverse effects from excessive doses of droperidol.

The pharmacist recommended alternative therapy in 47 cases, suggesting drugs that were safer or cheaper but equally effective, such as changing from intravenous to oral metoclopramide. Potential problems relating to drug interactions and drug allergies were identified by the pharmacist in 22 cases and use of alternative drugs was recommended.

Thirty-two of the pharmacist interventions did not relate to ordering. Among these, the pharmacist provided special order drugs or approved nonformulary use of a drug in 14 instances, identified 6 previously unrecognized ADEs, and uncovered 12 systems errors in the pharmacy dispensing system. One example of dispensing errors was that a medication was prepared for peripheral intravenous infusion when a smaller volume was required for central administration to minimize fluid load.

COMMENT

In previous studies, we demonstrated that nearly half of preventable ADEs resulted from errors in the prescribing process. [1] Prescribing errors frequently have a cascade effect, causing errors downstream in dispensing or administration. The major cause of prescribing errors was physicians' lack of essential drug and patient information at the time of ordering. [2]

One method of providing such information is computerized physician order entry, which has been shown to reduce the rate of serious medication errors by more than half. [9] Evans et al [10] have demonstrated that a computer-assisted management program for antibiotics can substantially reduce excessive use and misuse of antibiotics as well as reduce length of hospital stay and costs. However, most hospitals do not yet have computerized ordering by physicians, so incorporation of the pharmacist into the patient care team is a more feasible alternative at present, especially in units with high medication use.

We estimated the financial impact of the 66% reduction in ADEs. The cost of an ADE has been estimated at \$2000 to \$2500 per event in 1993. [11,12] However, the cost of a preventable ADE, one due to an error, was estimated at \$4685. [9] For the year 1995, we estimate that 58 ADEs were prevented. At \$4685 each, the cost reduction in this single unit would be approximately \$270,000 per year. The intervention required no additional resources and represented a different use of the existing pharmacist's time. Rather than spending time checking and correcting orders after they had been sent to the pharmacy, the pharmacist was involved at the time the order was written. While participating in rounds as a member of the patient care team, the pharmacist reduced ADEs both by preventing errors and by intercepting them. He prevented errors by providing information about doses, interactions, indications, and drug alternatives to physicians at the time of ordering. He intercepted errors by immediately reviewing all orders and correcting deficiencies before the orders were transmitted to the pharmacy. In addition, the pharmacist prevented nursing medication errors by providing ready consultation to the nursing staff and teaching drug safety.

Finally, the on-site pharmacist took overall responsibility for medication safety, spotting unsafe conditions and identifying needs for process improvement. For example, during the study period the pharmacist identified 12 systems errors in pharmacy function and 6 ADEs that probably would not have otherwise been discovered.

The presence of the pharmacist on rounds was well accepted by physicians, as evidenced by the fact that 99% of the recommendations were accepted. While staff perceptions were not evaluated systematically, in our experience, nurses also accepted this role easily, appreciating the reduction in extra work, such as telephoning physicians to have orders corrected. The pharmacist in this study had to overcome the traditional impression of the medical staff that pharmacists may be primarily concerned with costs. This academic medical ICU environment had the added challenge of dealing with a new group of house staff, fellows, and attending physicians every few weeks. In ICUs where the attending physicians are permanent and fellows are assigned for many months, acceptance might be enhanced.

Our study has several limitations. We studied only 1 ICU in 1 teaching hospital. Adverse drug events are more common in teaching hospitals than in community hospitals [13] and occur more frequently in ICUs, [1] so these findings are not generalizable to all types of units or all types of hospitals. However, the magnitude of the impact of the pharmacist's presence was so great that a substantial effect would probably be found in ICUs in other hospitals. Second, our results do not represent the full extent of preventable ADEs, since record review does not capture all events, nor does it capture most potential ADEs, the "near misses," because they are seldom recorded in patient charts. Third, physicians and nurses in this ICU function as a team and make rounds together. Pharmacist participation would be more difficult to arrange in units where multiple physicians make rounds at different times. Finally, the success of the pharmacist intervention depends on interpersonal relationships. Thus, the personality and cooperativeness of the pharmacist and the medical staff are critical factors in making this system work, especially at the beginning. Similar prevention of ADEs prompted by a designated ICU pharmacist probably would be less likely to occur in ICUs in which staff are not part of a multidisciplinary team and when ICU staff are not open to the important role that the pharmacist can play in optimizing ICU management.

We conclude that participation of a pharmacist on medical rounds can be a powerful means of reducing the risk of ADEs.

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